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(54) **RADIO FREQUENCY ELECTRIC POWER CONVERSION MECHANISM**

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H01P 5/107 (2006.01)
H01P 5/08 (2006.01)

(52) **U.S. Cl.**

CPC ***H01P 5/107*** (2013.01); *H01P 3/121* (2013.01)

(58) **Field of Classification Search**

CPC H01P 3/12; H01P 3/121; H01P 5/08
USPC 333/26, 246, 248
See application file for complete search history.

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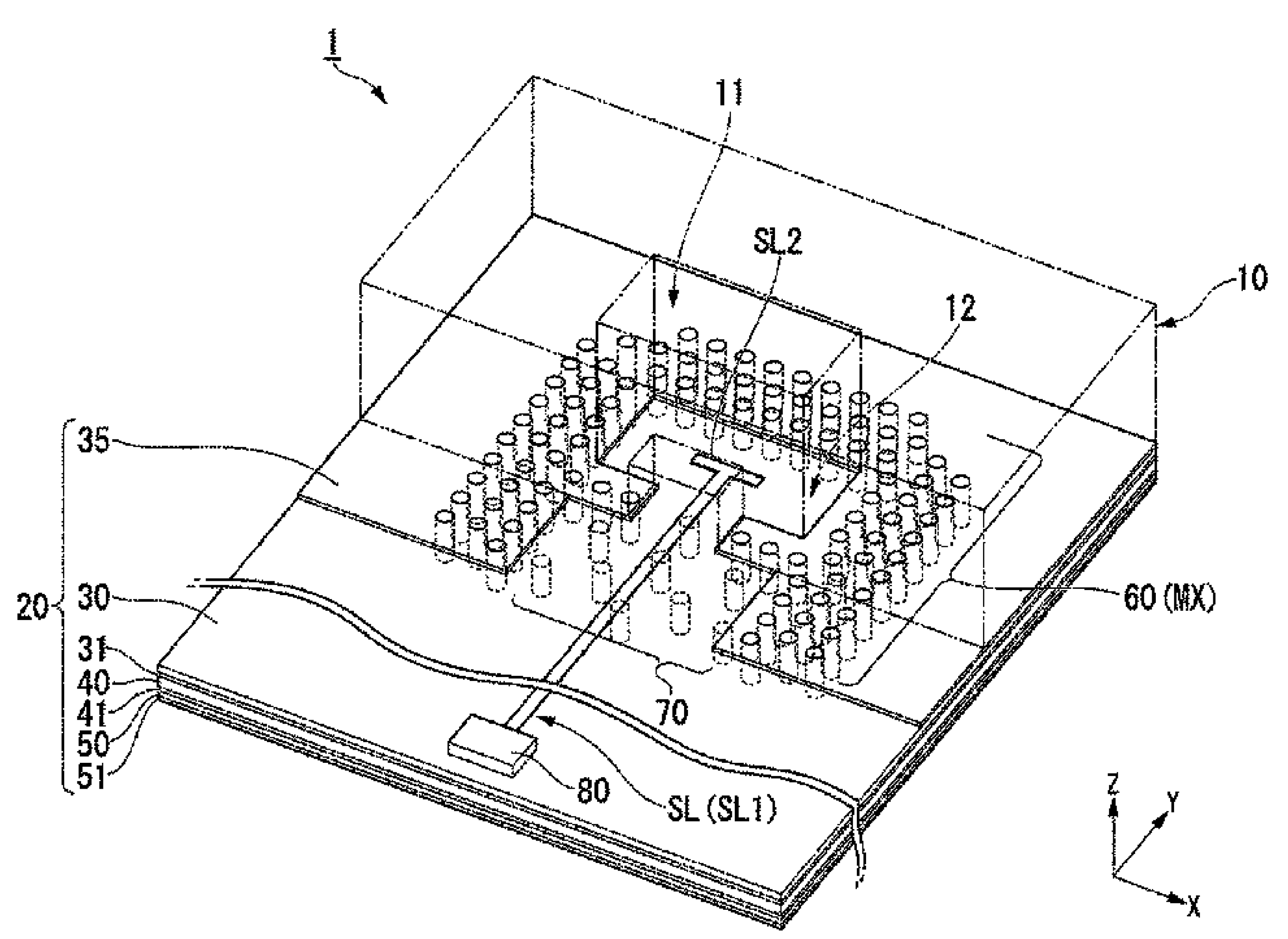
(57) **ABSTRACT**

A radio frequency electric power conversion mechanism of the present invention includes a circuit board including a fiber reinforced resin board, instead of an expensive ceramic circuit board. The radio frequency electric power conversion mechanism has a combined configuration of a plurality of fiber reinforced resin boards laminated to each other with a conductive foil therebetween, a via hole array made of an electric conductor passing through the boards, a transmission line closely adhered to the surface of a board, and a waveguide having a notch in a part of the waveguide on the aperture side. The radio frequency electric power conversion mechanism further has other structural features.

20 Claims, 5 Drawing Sheets



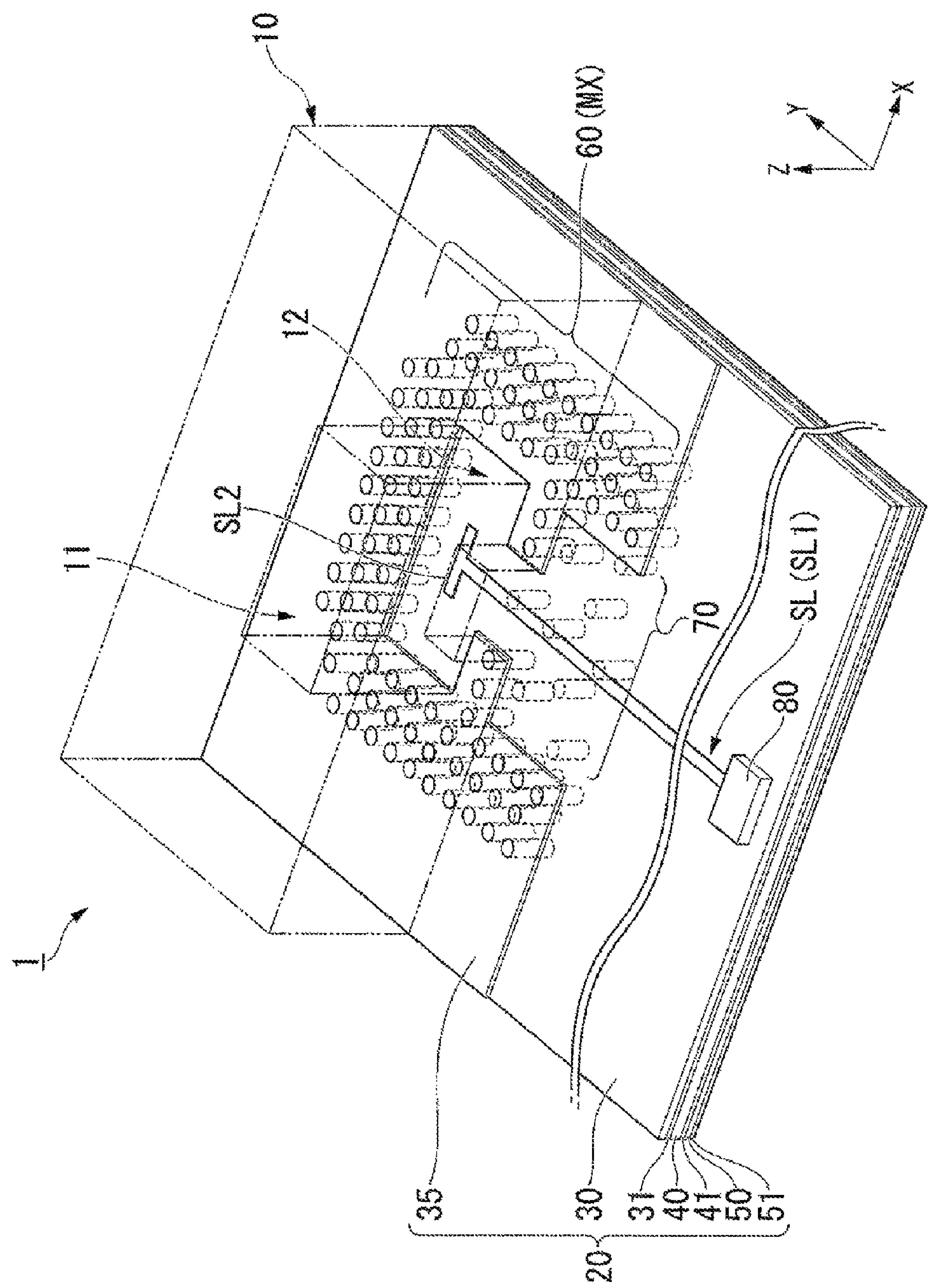


Fig. 1

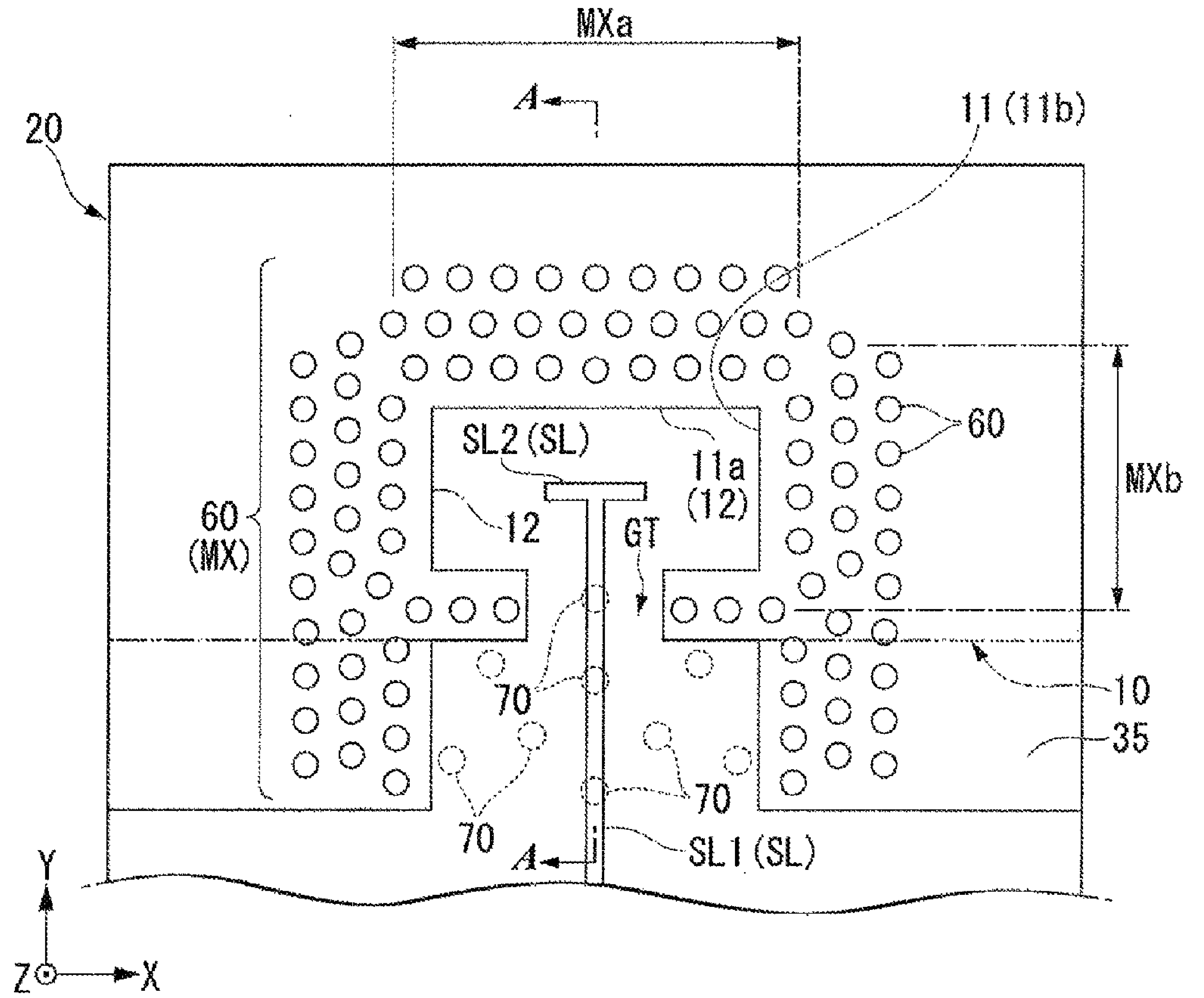

MXa
A
11 (11b)
20
60
SL2 (SL)
11a
(12)
MXb
60
(MX)
12
GT
10
35
70
70
70
A
SL1 (SL)
Y
Z
X

Fig. 2

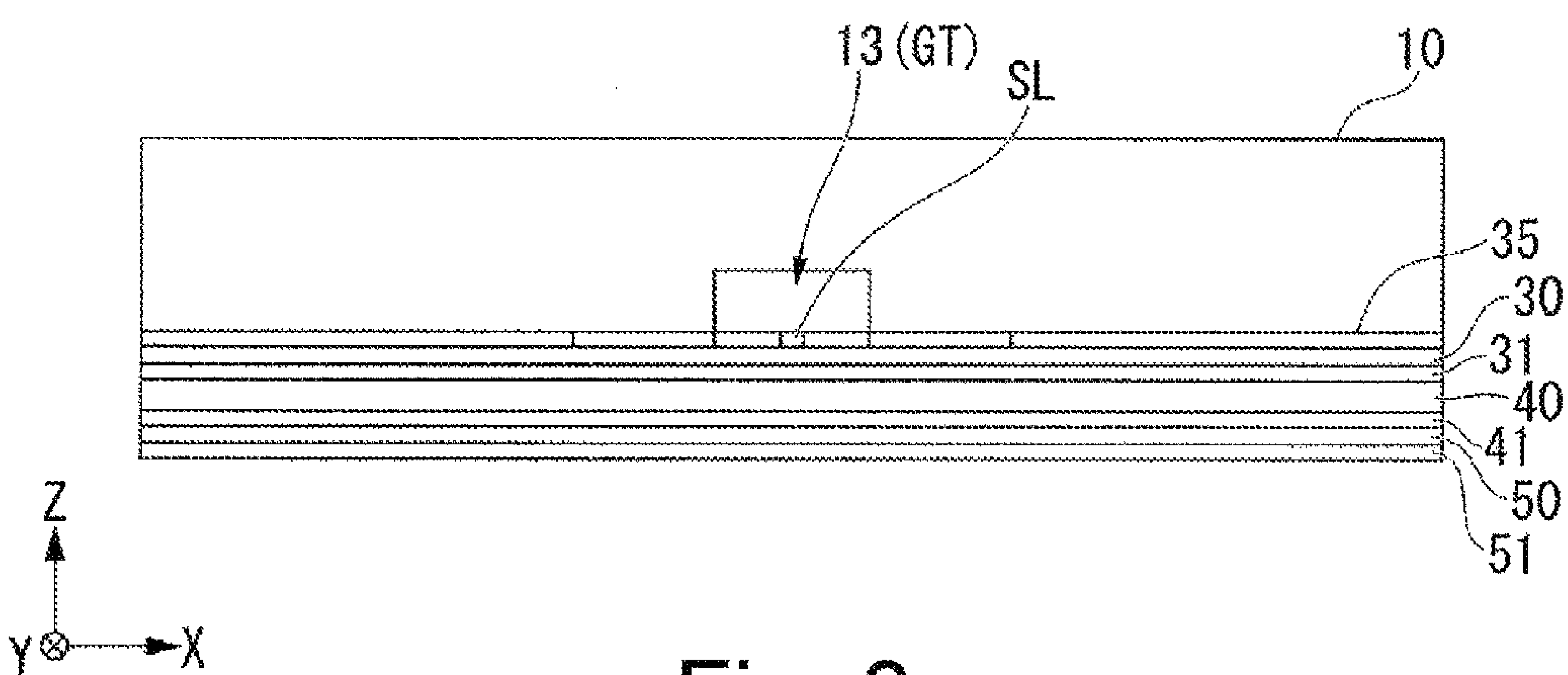

13 (GT)
SL
10
35
30
31
40
41
50
51
Z
Y
X

Fig. 3

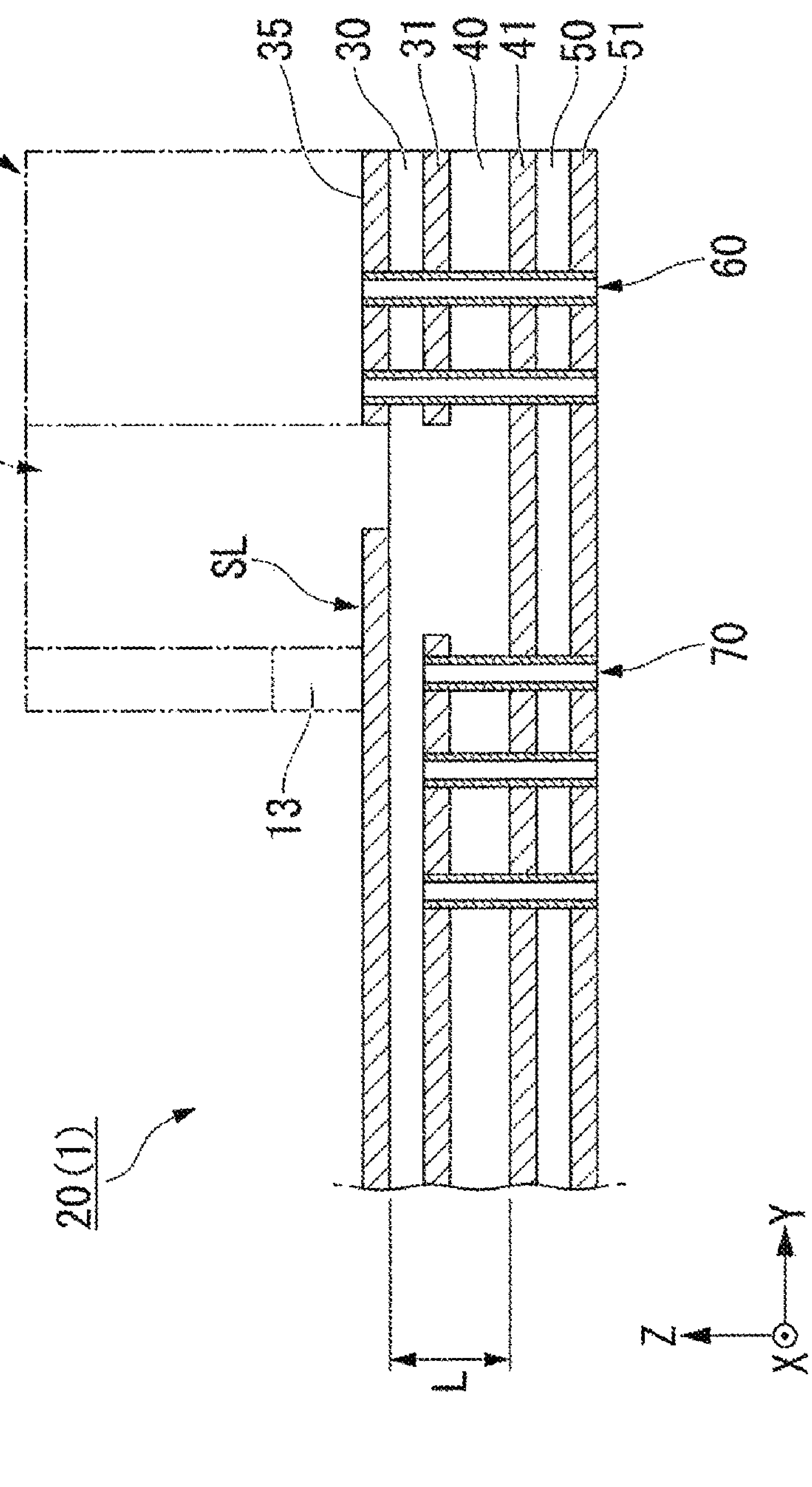


Fig. 4

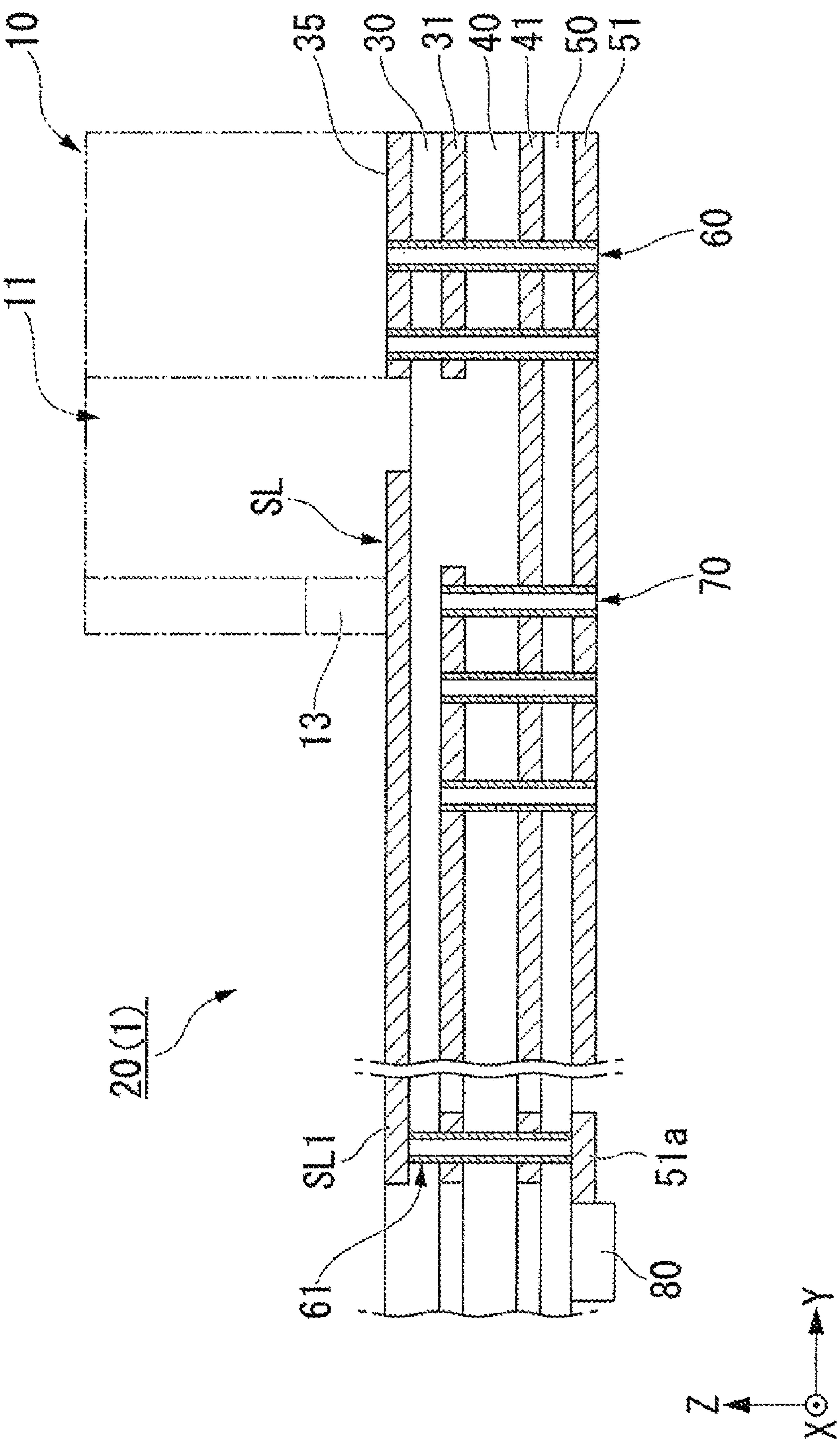


Fig. 5

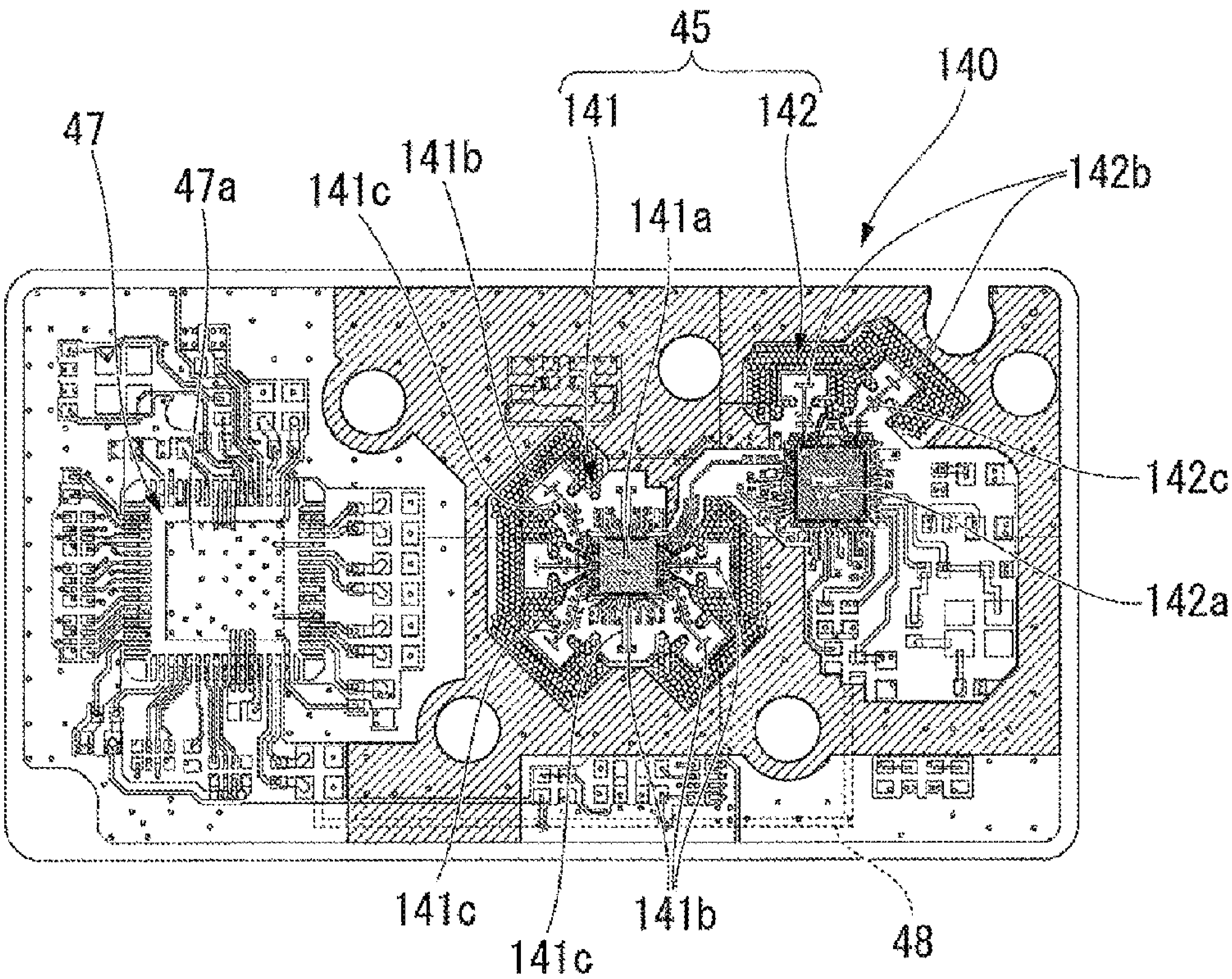

45
140
141
142
47
47a
141b
141c
141a
142b
142c
142a
141c
141c
141b
48

Fig. 6

RADIO FREQUENCY ELECTRIC POWER CONVERSION MECHANISM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a radio frequency electric power conversion mechanism.

2. Description of the Related Art

A radio frequency electric power conversion mechanism provided with a transmitter-receiver circuit and a waveguide is used when, for example, an electromagnetic wave having a short wavelength such as millimeter waves or microwaves used for a vehicle radar is transmitted or received by means of an antenna using the transmitter-receiver circuit. Such a transmitter-receiver circuit is integrated, for example, as a monolithic microwave integrated circuit (MMIC), in a substrate provided with a waveguide, a microstripline and a patch electrode. Radio frequency electric power emitted from the MMIC is converted into an electromagnetic wave in a certain transmission mode by means of the microstripline and the patch electrode and transmitted through the waveguide. On the other hand, the electromagnetic wave transmitted by the waveguide is converted into an electromagnetic wave in another transmission mode by means of the patch electrode and the microstripline and transmitted to the MMIC (see, for example, Japanese Patent Laid-Open No. 2013-172251).

SUMMARY OF THE INVENTION

The circuit board provided with the MMIC, the waveguide, the microstripline and the patch electrode described above causes a high production cost because of use of an expensive ceramic circuit board, for example, as disclosed in Japanese Patent Laid-Open No. 2013-172251.

The present invention has been made in view of the above problem, and an object of the present invention is to provide a radio frequency electric power conversion mechanism capable of reducing production cost.

A radio frequency electric power conversion mechanism of a first aspect of the present invention is a radio frequency electric power conversion mechanism including a waveguide and a circuit board having a plurality of fiber reinforced resin boards and a conductive foil, including:

a monolithic microwave integrated circuit (MMIC);

a first board made of fiber reinforced resin;

a transmission line which is a strip-like foil or a wire made of an electric conductor, the transmission line being adhered to the upper surface of the first board and having one end connected to the MMIC;

a first foil made of an electric conductor, the first foil being adhered to a lower surface of the first board and covering at least a region of the lower surface under a region where the transmission line is disposed;

a second board made of fiber reinforced resin and adhered to a lower surface of the first foil;

a second foil made of an electric conductor and adhered to a lower surface of the second board;

a waveguide extending in a direction away from the upper surface of the first board and including a cavity having a square-shaped cross-section therein; and

at least one surface layer via hole that is a conductive tube or pole passing through at least the first board and the second board, connected to the second foil, and having an upper end exposed to a surface of the circuit board; wherein

the waveguide has a square-shaped aperture on its lower end;

the at least one surface layer via hole includes a plurality of surface layer via holes, and at least part of the surface layer via holes constitutes an array surrounding at least three sides of the other end of the transmission line;

a lower end surface of the waveguide is adhered to upper end surfaces of the surface layer via holes constituting the array;

the array includes long side portions and short side portions where the surface layer via holes are arrayed along a long side and a short side of the aperture, respectively;

the surface layer via holes constituting the array are not positioned inside the aperture, as seen through the waveguide;

the array includes a gate portion where the array of the via holes is broken off in entirely one of the long side portions or in a part of the long side portions;

the waveguide has a notch opening toward the lower end surface in the side surface of the lower end of the waveguide;

the transmission line passes through the gate portion and reaches the inside of the array;

the notch is located over at least a region of the gate portion through which the transmission line passes;

the second foil covers at least a region of the lower surface of the second board located on an inner side of the array;

the MMIC is disposed in one of the upper and lower surfaces of the first or second board; and

the first foil, the second foil and the surface layer via holes constituting the square-shaped array are grounded.

The configuration of the present invention as described above can reduce production cost of a radio frequency electric power conversion mechanism.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a radio frequency electric power conversion mechanism, showing an preferred embodiment of the present invention.

FIG. **2** is a plan view partially showing a circuit board **20** on the plus Y side.

FIG. **3** is an elevation view of a waveguide **10** and the circuit board **20** in FIG. **2**, as seen from the minus Y side.

FIG. **4** is a cross-sectional view taken along the line A-A in FIG. **2**.

FIG. **5** is a partial cross-sectional view showing a modification in placement of a MMIC.

FIG. **6** is a plan view showing a modification where each of a receiving MMIC and a transmitting MMIC is individually provided in the circuit board.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An preferred embodiment of a radio frequency electric power conversion mechanism of the present invention will be described with reference to FIGS. **1** to **6**.

FIG. **1** is a perspective view of a radio frequency electric power conversion mechanism **1**.

The radio frequency electric power conversion mechanism **1** includes a waveguide **10** and a circuit board **20**. The circuit board **20** includes a first board **30**, a second board **40**, a third board **50**, a transmission line SL, a conductive foil **35**, a first foil **31**, a second foil **41**, a third foil **51**, a plurality of surface layer via holes **60** and a plurality of inner layer via holes **70**. The circuit board **20** is provided with a monolithic microwave integrated circuit (MMIC) **80**.

In the drawings, an X-Y-Z coordinate system is optionally shown as a three-dimensional orthogonal coordinate system. Illustratively, a Z axial direction is a direction in which the waveguide **10** is provided relative to the circuit board **20** shown in FIG. **1**, a Y axial direction is a direction in which the transmission line SL extends perpendicular to the Z axial direction and an X axial direction is a direction perpendicular to the Z axial direction and the Y axial direction. In the drawings, optionally illustratively, the upper side is the plus Z side and the lower side is the minus Z side. Also, in the drawings, to facilitate understanding of a configuration of the circuit board **20**, the waveguide **10** is optionally shown by a long dashed double-short dashed line.

The waveguide **10** is a transmission line to transmit a radio frequency electromagnetic wave. The waveguide **10**, as an example, may be made of aluminum. The waveguide **10** is placed in the upper surface of the circuit board **20**. The waveguide **10** extends in a direction away from the upper surface of the first board **30** and includes a cavity **11** having a square-shaped cross-section therein. The radio frequency electromagnetic wave is transmitted inside the cavity **11**. The waveguide **10** has a square-shaped aperture **12** in its lower end. The lower end surface of the waveguide **10** is adhered to the upper end surfaces of the surface layer via holes **60** described later.

The waveguide **10** may be, as an example, connected to an antenna on the upper end portion of the waveguide **10**. FIG. **2** is a plan view partially showing the circuit board **20** on the plus Y side. As shown by the long dashed double-short dashed line in FIG. **2**, a long side **11***a* of the cavity **11** in the cross-section of the waveguide **10** may be, as an example, equal to or larger than a half of a wavelength of a radio frequency electromagnetic wave in air, generated by the MMIC **80**, and smaller than the wavelength of the radio frequency electromagnetic wave in air, generated by the MMIC **80**. The short side **11***b* of the cavity **11** may be, as an example, equal to or larger than a quarter of the wavelength of the radio frequency electromagnetic wave in air, generated by the MMIC **80**, and equal to or smaller than a half of the wavelength.

FIG. **3** is an elevation view of the waveguide **10** and the circuit board **20** shown in FIG. **2**, as seen from the minus Y side. As shown by a solid line in FIG. **3**, the waveguide **10** has a notch **13** opening toward the lower end surface in the side surface on the minus Y side of the lower end of the waveguide **10**.

The first board **30** is made of fiber reinforced resin. The fiber reinforced resin is a raw material provided by impregnating a fiber material with resin. As the fiber material, a glass fiber and a carbon fiber may be used. An epoxy resin, a polyamide resin and a phenol resin are applicable as the resin. In this preferred embodiment, the first board **30** is made of a glass fiber reinforced epoxy resin. In the surface layer of the upper surface of the first board **30**, the transmission line SL and the conductive foil **35** are disposed.

The transmission line SL is a strip-like foil made of an electric conductor and adhered to the upper surface of the first board **30**. The transmission line SL may be, as an example, made of pure copper or copper alloy. As described later, for the transmission line SL, at least part of its surface may be covered with gold. The transmission line SL having at least the part of its surface covered with gold is also suitable for applications in which wire bonding is carried out by using gold.

The transmission line SL is connected at its one end to the MMIC **80**. The transmission line SL includes a first stripline SL**1** and a second stripline SL**2**. The first stripline SL**1** extends parallel to the short side **11***b* of the cavity **11**. The end of the first stripline SL**1** on the minus side along Y axis direction is connected to the MMIC **80**. The second stripline SL**2** extends in the X axis direction and is connected to the end on the plus side along Y axis direction of the first stripline SL**1**. The second stripline SL**2** forms a radiation element when the MMIC **80** generates a radio frequency electromagnetic wave. The second stripline SL**2** forms a receiving element when the MMIC **80** receives a radio frequency electromagnetic wave. The length of the second stripline SL**2** is equal to or larger than a quarter of a wavelength of a radio frequency electromagnetic wave in the upper surface of the first board **30**, generated by the MMIC **80**, and equal to or smaller than a half of the wavelength. Note that a modification in which the second stripline SL**2** is not present may be implemented. However, providing the second stripline SL**2** can enhance radiation efficiency of the radio frequency electromagnetic wave from the end of the first stripline SL**1** toward the waveguide.

The conductive foil **35** may be, as an example, made of pure copper or copper alloy. The conductive foil **35** is adhered to the upper surface of the first board **30**. The conductive foil **35** is grounded. That is, the conductive foil **35** is at the ground potential. The conductive foil **35**, as shown in FIG. **2**, is disposed at a position where it contacts with the waveguide **10** in the upper face of the first board **30**. As described later, in the upper face of the first board **30**, the conductive foil **35** connects the plurality of surface layer via holes **60** to one another. The conductive foil **35** is not disposed at a position where the upper face of the first board **30** faces to the cavity **11** and where the inner layer via holes **70** are arranged.

FIG. **4** is a cross-sectional view taken along the line A-A in FIG. **2**.

As shown in FIG. **4**, the surface layer via holes **60** pass through the first board **30**, the second board **40** and the third board **50**. The surface layer via holes **60** are connected to the first foil **31** and the second foil **41**. Upper ends of the surface layer via holes **60** are exposed to the surface of the circuit board **20**. Lower ends of the surface layer via holes **60** are connected to the third foil **51**. Each of the surface layer via holes **60** is a conductive tube. Each of the surface layer via holes **60** may be a conductive pole.

As shown in FIG. **2**, the surface layer via holes **60** form an array MX surrounding at least three sides of the second stripline SL**2** disposed in the end of the transmission line SL on the plus side along Y direction and a part of the first stripline SL**1**. The surface layer via holes **60** constituting the array MX are not situated inside the aperture **12**, as seen through the waveguide **10**.

The array MX includes a long side portion MXa where the surface layer via holes **60** are arrayed along the long side **11***a* of the aperture **12** of the waveguide **10** relative to the second stripline SL**2** and a part of the first stripline SL**1**. The array MX includes a short side portion MXb where the surface layer via holes **60** are arrayed along the short side **11***b* of the aperture **12** of the waveguide **10**. There is a space in a planar direction between the surface layer via holes **60** constituting the long side portion MXa and the short side portion MXb, and the edge of the aperture **12** of the waveguide **10**. The conductive foil **35** extends toward the cavity **11** side beyond the surface layer via holes **60** that are nearest to the cavity side of the surface layer via holes **60** constituting the long side portion MXa and the short side portion MXb. By giving a margin to the conductive foil **35** in such a manner, it becomes easier to form the surface layer via holes **60**.

The array MX has a gate portion GT where the surface layer via holes **60** of the array is not provided in part on the long side portion MXa on the minus side of the aperture **12** along Y axis direction. The transmission line SL described above passes through the gate portion GT and reaches the inside of the array MX. The notch **13** of the waveguide **10** described above is located over at least a region of the gate portion GT through which the transmission line SL passes.

The inner layer via holes **70**, as shown in FIG. **4**, pass through the second board **40** and the third board **50**. The inner layer via holes **70** are connected to the second foil **41**. The lower end of the inner layer via holes **70** is connected to the third foil **51**. The upper end of the inner layer via holes **70** is situated in the upper face of the second board **40** and connected to the first foil **31**. Each of the inner layer via holes **70** is a conductive tube. The inner layer via hole may be a conductive pole.

As shown in FIG. **2**, the inner layer via holes **70** are disposed directly below the gate portion GT relative to the array MX, or outside on the minus side along Y axis. The inner layer via holes **70** are disposed at a position where they are overlapped by the first stripline SL**1** of the transmission line SL, as seen in a planar view, and where the conductive foil **35** does not cover on both sides of the first stripline SL**1** in the X direction.

The first foil **31** is made of an electric conductor. A material of the first foil **31** may be, as an example, the same as the material of the conductive foil **35**. As shown in FIG. **4**, the first foil **31** is adhered to the lower surface of the first board **30**. The first foil **31** covers at least a region of the lower surface under a region where the transmission line SL is disposed. However, the first foil **31** does not exist inside the array MX and on the plus side away from the end of the gate portion GT toward the plus direction in Y axis direction.

The second board **40** is made of fiber reinforced resin. A material of the second board **40** may be, as an example, the same as the material of the first board **30**. The second board **40** is adhered to the lower surface of the first foil **31**.

The second foil **41** is made of an electric conductor. A material of the second foil **41** may be, as an example, the same as the material of the first foil **31**. The second foil **41** is adhered to the lower surface of the second board **40**. The second foil **41** covers at least a region of the lower surface of the second board **40** located on the inner side of the array MX. Inside the square-shaped array MX, the length L from the surface of the first board **30** to the second foil **41** is larger than a quarter of a wavelength of a radio frequency electromagnetic wave in the first board **30** and the second board **40** and smaller than a half of the wavelength. The radio frequency electromagnetic wave is generated by the MMIC **80**.

Note that the radio frequency electric power conversion mechanism of the present invention can be used for a frequency-modulated continuous-wave (FMCW) radar. In such a case, a frequency of a radio frequency electric power may have a width of the range in a practical sense, so that there is a width of the wavelength range. In such an application, the phrase "larger than a quarter of a wavelength" described above means "larger than a quarter of the smallest wavelength in a radio frequency band used". Similarly, the phrase "smaller than a half of a wavelength" means "smaller than a half of the largest wavelength in a radio frequency band used".

The third board **50** is made of fiber reinforced resin. A material of the third board **50** may be, as an example, the same as at least one of the first board **30** and the second board **40**. The third board **50** is adhered to the lower surface of the second foil **41**.

The third foil **51** is adhered to the lower surface of the third board **50**. The third foil **51** is grounded.

That is, the third foil **51** is at the ground potential. The conductive foil **35** and the third foil **51** are grounded, so that the first foil **31**, the second foil **41**, the surface layer via holes **60** and the inner layer via holes **70** are grounded.

One or more of any of the first board **30**, the second board **40** and the third board **50** may be a composite board including a plurality of boards and one or more foils. As the composite board, as an example, an FR-4 board used widely for a printed circuit board may be adopted. The FR-4 board can be provided by impregnating a glass fiber cloth with epoxy resin before curing and performing a thermosetting treatment of the resin.

The MMIC **80** can generate and receive a radio frequency electromagnetic wave in the frequency range of 70 GHz or more and 100 GHz or less. The MMIC **80** in this preferred embodiment, as an example, may generate and receive a radio frequency electromagnetic wave in the range whose center frequency is 76.5 GHz. The MMIC **80** is disposed in the upper surface of the first board **30**.

In the radio frequency electric power conversion mechanism **1** described above, a radio frequency electromagnetic wave generated by the MMIC **80** propagates through the first stripline SL**1** of the transmission line SL in a quasi-TEM mode and is converted from the quasi-TEM mode into a waveguide mode in the second stripline SL**2** that functions as a radiation element. The radio frequency electromagnetic wave in a quasi-TEM mode converted into the waveguide mode is radiated from the second stripline SL**2**. A radio frequency electromagnetic wave radiated toward the plus side along Z axis proceeds toward the cavity **11** of the waveguide **10**, while a radio frequency electromagnetic waves radiated toward the minus side along Z axis is reflected from the second foil **41** that forms a ground plane and then proceed toward the cavity **11** of the waveguide **10**. The waveguide **10** contacts with the conductive foil **35** and the surface layer via holes **60** in the lower end surface of the waveguide **10**. The surface layer via holes **60** are connected to the conductive foil **35**, the first foil **31**, the second foil **41** and the third foil **51**. The conductive foil **35** and the third foil are grounded, so that the radio frequency electromagnetic wave generated by the MMIC **80** is prevented from leaking out.

Generally, in order that a radio frequency electromagnetic wave is brought into a resonant condition and thus the maximum electric power is radiated, the distance L from the surface of the first board **30** to the second foil **41** is a quarter of the wavelength, in the relevant site, of the radio frequency electromagnetic wave generated by the MMIC **80**. In order that the radio frequency electromagnetic wave is brought into a resonant condition and thus the maximum electric power is radiated the length of the second stripline SL**2** is a quarter of the wavelength, in the upper surface of the first board **30**, of the radio frequency electromagnetic wave generated by the MMIC **80**.

The inventors of this application have found a condition in the radio frequency electric power conversion mechanism

1 described above in which transmission efficiency of a radio frequency electromagnetic wave is enhanced.

More specifically, when the distance L from the surface of the first board **30** to the second foil **41**, as described above, is larger than a quarter of a wavelength, in the relevant site, of a radio frequency electromagnetic wave generated by the MMIC **80**, and smaller than a half of the wavelength, then the transmission efficiency is enhanced. When the length of the second stripline SL**2** is equal to or larger than a quarter of the wavelength, in the upper surface of the first board **30**, of the radio frequency electromagnetic wave generated by the MMIC **80**, and equal to or smaller than a half of the wavelength, then the transmission efficiency is enhanced. When the distance L is larger than a quarter of the wavelength of the radio frequency electromagnetic wave inside the first board **30** and the second board **40**, and smaller than a half of the wavelength, and when the length of the second stripline SL**2** is equal to or larger than a quarter of the wavelength of the radio frequency electromagnetic wave, and equal to or smaller than a half of the wavelength, then the long side **11***a* of the cavity **11** of the waveguide **10** is preferably equal to or larger than a half of the wavelength in air of the radio frequency electromagnetic wave generated by the MMIC **80**, and smaller than the wavelength in air of the radio frequency electromagnetic wave generated by the MMIC **80**. When the distance L is larger than a quarter of the wavelength of the radio frequency electromagnetic wave, and smaller than a half of the wavelength, and when the length of the second stripline SL**2** is equal to or larger than a quarter of the wavelength of the radio frequency electromagnetic wave, and equal to or smaller than a half of the wavelength, then the short side **11***b* of the cavity **11**, as an example, is preferably equal to or larger than a quarter of the wavelength in air of the radio frequency electromagnetic wave generated by the MMIC **80**, and smaller than a half of the wavelength.

Conventionally, the distance L has been preferably equal to a quarter of a wavelength of a radio frequency electromagnetic wave. It is considered that one reason why the transmission efficiency is enhanced when the distance L is larger than a quarter of the wavelength of the radio frequency electromagnetic wave, and smaller than a half of the wavelength is because the width of the long side portion MXa of the array MX, especially the width measured between edges of the via holes **60** on the inner side is slightly larger than the width of the cavity **11** of the waveguide **10** in the long side direction. Accordingly, the resonant condition of the radio frequency electromagnetic wave changes, and the distance L is set to a larger value than usual, thereby enhancing the transmission efficiency.

According to this preferred embodiment, the first board **30**, the second board **40** and the third board **50** are made of fiber reinforced resin. According to this preferred embodiment, a radio frequency electromagnetic wave can be radiated or received without use of an expensive ceramic circuit board. Therefore, this preferred embodiment can provide a radio frequency electric power conversion mechanism capable of being reduced in production cost.

According to this preferred embodiment, because the radio frequency electric power conversion mechanism **1** includes the surface layer via holes **60** and the inner layer via holes **70**, leaking out of a radio frequency electromagnetic wave could change the resonant condition. According to this preferred embodiment, inside the square-shaped array MX, the distance L from the surface of the first board **30** to the second foil **41** is larger than a quarter of a wavelength, in the relevant site, of a radio frequency electromagnetic wave generated by the MMIC **80**, and smaller than a half of the wavelength. According to this preferred embodiment, when the MMIC **80** capable of generating and receiving a radio frequency wave within the frequency range of 70 GHz or more and 100 GHz or less is used, the transmission efficiency of the radio frequency electromagnetic wave can be enhanced.

According to this preferred embodiment, the inner layer via holes **70** are disposed outside the gate portion GT relative to the array MX. Therefore, according to this preferred embodiment, the radio frequency electromagnetic wave can be prevented from leaking out through the gate portion GT.

The preferred embodiment according to the present invention has been described above with reference to the accompanying drawings, and it goes without saying that the present invention is not limited to such an preferred embodiment. Various shapes and combinations of each of components shown in the preferred embodiment described above are one example, and various changes may be made based on engineering requirements without departing from the spirit and scope of the present invention.

For example, in the above preferred embodiment, the configuration including the third board **50** and the third foil **51** has been illustrated, but a configuration without the third board **50** and the third foil **51** may be implemented. In the configuration without the third board **50** and the third foil **51**, the surface layer via holes **60** pass through the first board **30** and the second board, and are connected to the conductive foil **35**, the first foil **31** and the second foil **41**. In the configuration without the third board **50** and the third foil **51**, the inner layer via holes **70** pass through the second board **40**, and are connected to the first foil **31** and the second foil **41**.

The site where the array MX is positioned, shown in the above preferred embodiment, may be provided with a fourth board made of fiber reinforced resin and covering at least part of the upper surface of the first board **30**. If the configuration including the fourth board is adopted, preferably, the surface layer via holes **60** pass through the fourth board, and the upper end of the surface layer via holes **60** is exposed to the upper surface of the fourth board.

In the above preferred embodiment, the example where the MMIC **80** is disposed in the upper surface of the first board **30** has been illustrated. The MMIC **80**, as an example, may be disposed in the lower surface of the third board **50**, as shown in FIG. **5**. If the MMIC **80** is disposed in the lower surface of the third board **50**, a third foil **51***a* connected to the MMIC **80** is provided separately from the third foil **50**. The third foil **51***a* is connected to the first stripline SL**1** by through via holes **61** passing through the first board **30**, the second board **40** and the third board **50**.

Next, a modification in which each of a receiving MMIC and a transmitting MMIC is individually provided in the same circuit board is shown in FIG. **6**. In FIG. **6**, the view of the waveguide **10** is omitted.

A circuit board **140** is provided with a receiving radio frequency circuit portion **141**, a transmitting radio frequency circuit portion **142** and an information processing circuit portion **47**. In the circuit board **140**, the information processing circuit portion **47**, the radio frequency circuit portion **141** and the radio frequency circuit portion **142** are arranged in a plane so as not to be superposed on each other. The radio frequency circuit portion **141** and the radio frequency circuit portion **142** are disposed adjacent to each other, thus providing a radio frequency circuit region **45** as a whole. The circuit board **140** is provided with a signal line **48** to connect the radio frequency circuit portion **141**, the radio frequency circuit portion **142** and the information processing circuit portion **47** to each other.

The information processing circuit portion **47** includes an information processing integrated circuit **47***a*. The information processing integrated circuit **47***a* functions to control the radio frequency circuit portion **141** and the radio frequency circuit portion **142**, and process information. More particularly, the information processing integrated circuit **47***a* issues an order through the signal line **48** for the radio frequency circuit portion **142** to transmit a radio frequency electromagnetic wave. Also, the information processing integrated circuit **47***a* calculates information about reception of the radio frequency electromagnetic wave in the radio frequency circuit portion **141** through the signal line **48**.

The radio frequency circuit portion **141** includes a receiving MMIC **141***a*, and five transmission lines (microstripline) **141***c* extending from the MMIC **141***a* and having a second stripline **141***b* on their end as an individual receiving terminal.

The radio frequency circuit portion **142** includes a transmitting MMIC **142***a*, and two transmission lines (microstripline) **142***c* extending from the MMIC **142***a* and having a second stripline **142***b* on their end as an individual transmitting terminal.

The receiving terminal **141***b* of the radio frequency circuit portion **141** receives a radio frequency electromagnetic wave propagating from the waveguide **10** and transmits it to the MMIC **141***a*.

The transmitting terminal **142***b* of the radio frequency circuit portion **142** radiates an electromagnetic wave transmitted from the MMIC **142***a*.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A radio frequency electric power conversion mechanism including a waveguide and a circuit board having a plurality of fiber reinforced resin boards, comprising:

a monolithic microwave integrated circuit (MMIC);

a first board made of fiber reinforced resin;

a transmission line which is a strip-like foil or a wire made of an electric conductor, the transmission line being adhered to an upper surface of the first board and having one end connected to the MMIC;

a first foil made of an electric conductor, the first foil being adhered to a lower surface of the first board and covering at least an area of the lower surface under a region where the transmission line is disposed;

a second board made of fiber reinforced resin and adhered to a lower surface of the first foil;

a second foil made of an electric conductor and adhered to a lower surface of the second board;

a waveguide extending in a direction away from the upper surface of the first board and including a cavity having a square-shaped cross-section therein; and

plural surface layer via holes each of which is a conductive tube or pole passing through at least the first board and the second board, connected to the second foil, and having an upper end exposed to a surface of the circuit board; wherein

the waveguide has a square-shaped aperture on its lower end;

at least part of the plural surface layer via holes constitute an array surrounding at least three sides of the other end of the transmission line;

a lower end surface of the waveguide is adhered to upper end faces of the surface layer via holes constituting the array;

the array includes a long side portion and a short side portion where the surface layer via holes are arranged along a long side and a short side of the aperture, respectively;

the surface layer via holes constituting the array are not positioned inside the aperture, as seen through the waveguide guide;

the array includes a gate portion where the surface via holes is not provided entirely on one of the long side portions or in part on the long side portions;

the waveguide includes a notch opening toward the lower end surface in the side surface of the lower end of the waveguide;

the transmission line passes through the gate portion and reaches the inside of the array,

the notch is located over at least a region of the gate portion through which the transmission line passes;

the second foil covers at least a region of the lower surface of the second board located on an inner side of the array;

the MMIC is disposed in one of the upper and lower surfaces of the first or second board;

the first foil, the second foil and the surface layer via holes constituting the array are grounded;

a long side of a cross-section of the waveguide is equal to or larger than a half of a wavelength of a radio frequency electromagnetic wave in air, generated by the MMIC, and smaller than the wavelength; and

a short side of the cross-section of the waveguide is equal to or larger than a quarter of the wavelength of the radio frequency electromagnetic wave in air, generated by the MMIC, and equal to or smaller than a half of the wavelength.

2. The radio frequency electric power conversion mechanism according to claim **1**, wherein

the MMIC can generate and receive a radio frequency wave having a frequency range of 70 GHz or more and 100 GHz or less; and

on the inner side of the square-shaped array, a distance from a surface of the first board to the second foil is larger than a quarter of a wavelength of a radio frequency electromagnetic wave and smaller than a half of the wavelength.

3. The radio frequency electric power conversion mechanism according to claim **1**, further comprising:

a conductive foil connecting the surface layer via holes constituting the array with one another in the upper surface of the first board, wherein

a space exists, in a planar direction, between an edge of the aperture of the waveguide and the surface layer via holes constituting the long side portion, and between the edge of the aperture of the waveguide and the short side portion of the array.

4. The radio frequency electric power conversion mechanism according to claim **2**, further comprising:

a conductive foil connecting the surface layer via holes constituting the array with one another in the upper surface of the first board, wherein

a space exists, in a planar direction, between an edge of the aperture of the waveguide and the surface layer via holes constituting the long side portion, and between the edge of the aperture of the waveguide and the short side portion of the array.

5. The radio frequency electric power conversion mechanism according to claim **1**, further comprising:
a third board made of fiber reinforced resin and adhered to a lower surface of the second foil, wherein
the surface layer via holes pass through the third board; and
one or more of the first board, the second board and the third board are a composite board including a plurality of boards and one or more foils.

6. The radio frequency electric power conversion mechanism according to claim **2**, further comprising:
a third board made of fiber reinforced resin and adhered to a lower surface of the second foil, wherein
the surface layer via holes pass through the third board; and
one or more of the first board, the second board and the third board are a composite board including a plurality of boards and one or more foils.

7. The radio frequency electric power conversion mechanism according to claim **3**, further comprising:
a third board made of fiber reinforced resin and adhered to a lower surface of the second foil, wherein
the surface layer via holes pass through the third board; and
one or more of the first board, the second board and the third board are a composite board including a plurality of boards and one or more foils.

8. The radio frequency electric power conversion mechanism according to claim **4**, further comprising:
a third board made of fiber reinforced resin and adhered to a lower surface of the second foil, wherein
the surface layer via holes pass through the third board; and
one or more of the first board, the second board and the third board are a composite board including a plurality of boards and one or more foils.

9. The radio frequency electric power conversion mechanism according to claim **1**, further comprising:
at least one inner layer via hole that is a conductive tube or pole passing through the second board, and has a lower end connected to the second foil and an upper end positioned in an upper surface of the second board; wherein
the at least one inner layer via hole is positioned outside the gate portion relative to the array.

10. The radio frequency electric power conversion mechanism according to claim **2**, further comprising:
at least one inner layer via hole that is a conductive tube or pole passing through the second board, and has a lower end connected to the second foil and an upper end positioned in an upper surface of the second board; wherein
the at least one inner layer via hole is positioned outside the gate portion relative to the array.

11. The radio frequency electric power conversion mechanism according to claim **8**, further comprising:
at least one inner layer via hole that is a conductive tube or pole passing through the second board, and has a lower end connected to the second foil and an upper end positioned in an upper surface of the second board; wherein
the at least one inner layer via hole is positioned outside the gate portion relative to the array.

12. The radio frequency electric power conversion mechanism according to claim **1**, wherein
the transmission line includes a first stripline extending in a direction parallel to the short side and having one end connected to the MMIC and a second stripline extending in a direction intersecting the first stripline and connected to the other end of the first stripline.

13. The radio frequency electric power conversion mechanism according to claim **2**, wherein
the transmission line includes a first stripline extending in a direction parallel to the short side and having one end connected to the MMIC and a second stripline extending in a direction intersecting the first stripline and connected to the other end of the first stripline.

14. The radio frequency electric power conversion mechanism according to claim **11**, wherein
the transmission line includes a first stripline extending in a direction parallel to the short side and having one end connected to the MMIC and a second stripline extending in a direction intersecting the first stripline and connected to the other end of the first stripline.

15. The radio frequency electric power conversion mechanism according to claim **1**, further comprising:
a surface layer foil made of an electric conductor and adhered to the upper surface of the first board, wherein
the transmission line is a part of the surface layer foil: and
at least part of a surface of the surface layer foil is covered with gold.

16. The radio frequency electric power conversion mechanism according to claim **14**, further comprising:
a surface layer foil made of an electric conductor and adhered to the upper surface of the first board, wherein
the transmission line is a part of the surface layer foil: and
at least part of a surface of the surface layer foil is covered with gold.

17. The radio frequency electric power conversion mechanism according to claim **1**, further comprising:
at a site where the array is positioned, a fourth board made of fiber reinforced resin and covering at least part of the upper surface of the first board; wherein
the surface layer via holes pass through the fourth board, and
the upper ends of the surface layer via holes are exposed to an upper surface of the fourth board.

18. The radio frequency electric power conversion mechanism according to claim **16**, further comprising:
at a site where the array is positioned, a fourth board made of fiber reinforced resin and covering at least part of the upper surface of the first board; wherein
the surface layer via holes pass through the fourth board, and
the upper ends of the surface layer via holes are exposed to an upper surface of the fourth board.

19. The radio frequency electric power conversion mechanism according to claim **1**, wherein
the fiber reinforced resin is a glass epoxy resin; and
the first foil and the second foil are made of pure copper or copper alloy.

20. The radio frequency electric power conversion mechanism according to claim **18**, wherein
the fiber reinforced resin is a glass epoxy resin; and
the first foil and the second foil are made of pure copper or copper alloy.

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